Chapter C2: Summary of Case Study Results

Introduction

This chapter summarizes the results of the eight case study analyses. Each case study section reports EPA's estimate of the number of age 1 equivalent fish that are lost to I&E at the case study facilities and the economic value of these losses. The final section presents EPA's extrapolation of the losses from five case studies to estimates of national I&E losses.

Chapter Contents

C2-1 The Delaware Estuary Watershed Study (Mid-Atlantic Estuaries)

To evaluate potential I&E impacts of cooling water intake structures in the Delaware Estuary transition zone, EPA evaluated I&E rates at Salem Nuclear Generating Station located in the transition zone of the Delaware Estuary. EPA estimated that the impingement impact of Salem Nuclear Generating Station is over 3.1 million age 1 equivalent fish and over 135,900 pounds of lost fishery yield per year. The entrainment impact is over 356.3 million age 1 equivalent fish and 9.9 million pounds of lost fishery yield. Extrapolation of these losses to four other facilities indicated a cumulative impingement impact of over 12.2 million age 1 fish and a cumulative entrainment impact of over 526 million age 1 equivalent fish each year (Table C2-1). These results indicate that the cumulative impacts of multiple cooling water intake structures (CWIS) in a single area can be substantial.[1]

Table C2-1: Baseline Impacts (annual average) for the Delaware Estuary Transition Zone (Four In-Scope Facilities)

Baseline Impacts	Impingement	Entrainment
Age 1 equivalent fish lost	>12.2 million/yr	> 526.3 million/yr
# lbs lost to landed fishery	> 374,000 lb/yr	> 13.8 million lb/yr
$ value of loss ($2001)	$0.50 million - $0.8 million/yr	$16.8 million - $30.5 million/yr

Source: U.S. EPA analysis, 2002.

Average losses at the four in-scope facilities are valued (using benefits transfer combined with RUM recreation estimates) to range from $0.5 million to $0.8 million per year for impingement and from $16.8 to $30.5 million per year for entrainment (all in $2001).

[1] For an estimation of lost fishery yield per year and age 1 equivalent fish each year, see *Chapter B3: Ecological Risk Assessment* in *Part B:The Delaware Estuary* of the *Watershed Case Study Analysis for the Proposed Section 316(b) Phase II Existing Facilities Rule*.

In this estuarine setting, benefits attributed to reducing losses due to both impingement and entrainment may be quite large in terms of numbers of fish and in terms of the portion of benefits that could be monetized. This reflects the typical richness of estuary waters as important nursery locations for many important aquatic species. In addition, the higher benefit associated with entrainment reflects the high vulnerability of abundant early life stages of estuarine species, and indicates the relative importance of entrainment controls in estuary areas.

In part, EPA's recreational benefits estimates for the Delaware Estuary are based on a random utility model (RUM) analysis of recreational fishing benefits from reduced I&E. The RUM application in the Delaware Estuary focuses on weakfish and striped bass fishing valuation. Several recreational fishing studies have valued weakfish and striped bass, but values specific to these studies are not available. The study area includes recreational fishing sites at the Delaware River Estuary and the Atlantic coasts of Delaware and New Jersey.

EPA used data for this case study from the Marine Recreational Fishery Statistics Survey (MRFSS), combined with the 1994 Add-on MRFSS Economic Survey (AMES). The study used MRFSS information on angler characteristics and angler preferences, such as where they go fishing and what species they catch, to infer their values for changes in recreational fishing quality. EPA estimated angler behavior using a RUM for single-day trips. The study used standard assumptions and specifications of the RUM model that are readily available from the recreation demand literature. Among these assumptions are that anglers choose fishing mode and then the site in which to fish; and that anglers' choice of target species is exogenous to the model. EPA modeled an angler's decision to visit a site as a function of site-specific cost, fishing trip quality, presence of boat launching facilities, and water quality.

The quality of a recreational fishing trip is expressed in terms of the number of fish caught per hour of fishing. Catch rate is the most important attribute of a fishing site from the angler's perspective. This attribute is also a policy variable of concern because catch rate is a function of fish abundance, which may be affected by fish mortality caused by I&E.

The Agency combined the estimated model coefficients with the estimated changes in I&E associated with various cooling water intake structure technologies to estimate per trip welfare losses from I&E at the cooling water intake structures located in the Delaware Estuary transition zone. The estimated economic values of recreational losses from I&E at the 12 cooling water intake structures located in the case study area are $0.75, $2.04, and $9.97 per trip for anglers not targeting any particular species and anglers targeting weakfish and striped bass, respectively (all in $2001). EPA then estimated benefits of reducing I&E of two species — weakfish and striped bass — at the four in-scope cooling water intake structures in the case study area. The estimated values of an increase in the quality of fishing sites from reducing I&E at the in-scope cooling water intake structures are $0.52, $1.40 and $6.90 per trip for no target anglers and anglers targeting weakfish and striped bass, respectively (all in $2001).

EPA also examined the effects of changes in fishing circumstances on fishing participation during the recreational season. First, the Agency used the negative binomial form of the Poisson model to model an angler's decision concerning the number of fishing trips per recreation season. The number of fishing trips is modeled as function of the individual's socioeconomic characteristics and estimates of individual utility derived from the site choice model. The Agency then used the estimated model coefficients to estimate percentage changes in the total number of recreational fishing trips due to improvements in recreational site quality. EPA combined fishing participation data for Delaware and New Jersey obtained from MFRSS with the estimated percentage change in the number of trips under various policy scenarios to estimate changes in total participation stemming from changes in the fishing site quality in the study area. The MRFSS fishing participation data include information on both single-day and multiple-day trips. The Agency assumed that per day welfare gain from improved fishing site quality is independent of trip length. EPA therefore calculated total fishing participation for this analysis as the sum of the number of single-day trips and the number of fishing days corresponding to multiple-day trips. Analysis results indicate that improvements in fishing site quality from reducing I&E at all in-scope facilities will increase the total number of fishing days in Delaware and New Jersey by 9,464.

EPA combined fishing participation estimates with the estimated per trip welfare gain under various policy scenarios to estimate the value to recreational anglers of changes in catch rates resulting from changes in I&E in the Delaware Estuary transition zone. EPA calculated low and high estimates of economic values of recreational losses from I&E by multiplying the estimated per trip welfare gain by the baseline and policy scenario number of trips, respectively. The estimated recreational losses ($2001) to Delaware and New Jersey anglers from I&E of two species at all Phase 2 facilities in the transitional estuary and at all facilities in the transitional estuary range from $0.2 to $0.3 and from $7.2 to $13.2 million, respectively. Using similar calculations, the Agency estimated that reducing I&E of weakfish and striped bass at the four in-scope cooling water intake structures in the transition zone will generate $5.2 to $9.3 million ($2001) annually in recreational fishing benefits alone to Delaware and New Jersey anglers.

In interpreting the results of the Delaware case study, it is important to consider several critical caveats and limitations of the analysis. First, EPA believes that it has conservatively estimated cumulative impacts on Delaware Estuary species by considering only the I&E impacts of transition zone cooling water intake structures. In fact, many of the species affected by cooling water intake structures within the transition zone move in and out of this area, and therefore may be exposed to many more cooling water intake structures than considered here.

Second, the economic valuation of I&E losses is often complicated by the lack of market value for forage species, which may comprise a large proportion of total losses. EPA estimates that more than 450 million age 1 equivalents of bay anchovy may be lost to entrainment at transition zone cooling water intake structure each year (over 85 percent of the total of over 526 million estimated lost age 1 individuals for all species combined). Bay anchovy has no direct market value, but it is nonetheless a critical component of estuarine food webs. EPA included forage species impacts in the economic benefits calculations, but the final estimates may well underestimate the full value of the losses imposed by I&E. Thus, on the whole, EPA believes the estimates developed here probably understate the economic benefits of reducing I&E in the Delaware Estuary transition zone.

C2-2 Tampa Bay Watershed Study (Gulf Coast Estuary)

To evaluate potential I&E impacts of cooling water intake structures in estuaries of the Gulf Coast and Southeast Atlantic, EPA evaluated I&E rates at the Big Bend facility in Tampa Bay. EPA estimated that the impingement impact of Big Bend is 420,000 age 1 equivalent fish and over 11,000 pounds of lost fishery yield per year. The entrainment impact is 7.71 billion age 1 equivalent fish and nearly 23 million pounds of lost fishery yield per year. Extrapolation of these losses to other Tampa Bay facilities indicated a cumulative impingement impact of 1 million age 1 fish (27,000 pounds of lost fishery yield) and a cumulative entrainment impact of 19 billion age 1 equivalent fish (56 million pounds of lost fishery yield) each year.

The results of EPA's evaluation of the dollar value of I&E losses at Big Bend, as calculated using benefits transfer, indicate that baseline economic losses range from $60,000 to $66,000 per year for impingement and from $7.1 million to $7.3 million per year for entrainment (all in $2001). Baseline economic losses using benefits transfer for all in-scope facilities in Tampa Bay (Big Bend, PL Bartow, FJ Gannon, and Hookers Point) range from $150,000 to $163,000 per year for impingement and from $17.0 million to $18.0 million per year for entrainment (all in $2001).

EPA also developed a RUM approach to estimate the effects of improved fishing opportunities due to reduced I&E in the Tampa Bay Region. Cooling water intake structures withdrawing water from Tampa Bay impinge and entrain many of the species sought by recreational anglers. These species include spotted seatrout, black drum, sheepshead, pinfish, and silver perch. The study area includes Tampa Bay itself and coastal sites to the north and south of Tampa Bay.

The study's main assumption is that anglers will get greater satisfaction, and thus greater economic value, from sites where the catch rate is higher, all else being equal. This benefit may occur in two ways: first, an angler may get greater enjoyment from a given fishing trip when catch rates are higher, and thus get a greater value per trip; second, anglers may take more fishing trips when catch rates are higher, resulting in greater overall value for fishing in the region.

EPA's analysis of improvements in recreational fishing opportunities in the Tampa Bay Region relied on a subset of the 1997 MRFSS combined with the 1997 AMES and the follow-up telephone survey for the southeastern United States. The Agency evaluated five species and species groups in the model: drums (including red and black drum), spotted seatrout, gamefish, snapper-grouper, and all other species. I&E was found to affect black drum, spotted seatrout, and sheepshead, which is included in the snapper-grouper species category.

EPA estimated both a random utility site choice model and a negative binomial trip participation model. The random utility model assumes that anglers choose the site that provides them with the greatest satisfaction, based on the characteristics of different sites and the travel costs associated with visiting different sites. The trip participation model assumes that the total number of trips taken in a year are a function of the value of each site to the angler and characteristics of the angler.

To estimate changes in the quality of fishing sites under different policy scenarios, EPA relied on the recreational fishery landings data by state and the estimates of recreational losses from I&E on the relevant species at the Tampa Bay CWISs. The Agency estimated changes in the quality of recreational fishing sites under different policy scenarios in terms of the percentage change in the historical catch rate. EPA divided losses to the recreational fishery from I&E by the total recreational landings for the Tampa Bay area to calculate the percentage change in historical catch rate from baseline losses (i.e., eliminating I&E completely).

The results show that anglers targeting black drum have the largest per-trip welfare gain ($7.18 in $2001) from eliminating I&E in the Tampa region. Anglers targeting spotted seatrout and sheepshead have smaller per-trip gains ($1.80 and $1.77 respectively, in $2001). The large gains for black drum are due to the large predicted increase in catch rates. In general, based on a hypothetical one fish per trip increase in catch rate, gamefish and snapper-grouper are the most highly valued fish in the study area, followed by drums and spotted seatrout.

EPA calculated total economic values by combining the estimated per trip welfare gain with the total number of trips to sites in the Tampa Bay region. EPA used the estimated trip participation model to estimate the percentage change in the number of fishing trips with the elimination of I&E. These estimated percentage increases are 0.93 percent for anglers who target sheepshead,0 .94 percent for anglers who target spotted seatrout, and 3.82 percent for anglers who target black drum.

If I&E were eliminated in the Tampa region, EPA estimated total benefits to be $2,428,000 per year at the baseline number of trips, and $2,458,000 per year at the predicted increased number of trips (all in $2001). At the baseline number of trips, the I&E benefits to black drum anglers are $270,000 per year; benefits to spotted seatrout anglers are $2,016,000 per year; and benefits to sheepshead anglers are $143,000 per year (all in $2001).

EPA merged the results for the RUM analysis with the benefits transfer-based estimates to create an estimate of recreational fishery losses from I&E in a manner that avoids double counting of the recreation impacts. Baseline economic losses combining both approaches for all in-scope facilities in Tampa Bay (Big Bend, PL Bartow, FJ Gannon, and Hookers Point) range from $0.80 million to $0.82 million per year for impingement and from $20.0 million to $20.9 million per year for entrainment (all in $2001) (see Table C2-2).

For a variety of reasons, EPA believes that the estimates developed here underestimate the value of I&E losses at Tampa Bay facilities. EPA assumed that the effects of I&E on fish populations are constant over time (i.e., that fish kills do not have cumulatively greater impacts on diminished fish populations). EPA also did not analyze whether the number of fish affected by I&E would increase as populations increase in response to improved water quality or other improvements in environmental conditions. In the economic analyses, EPA also assumed that fishing is the only recreational activity affected.

Table C2-2: Baseline Impacts (annual average) for Tampa Bay (Four In-Scope Facilities)

Baseline Impacts	Impingement	Entrainment
Age 1 equivalent fish lost	> 1 million/yr	> 19 billion/yr
# lbs lost to landed fishery	> 27,000 lb/yr	> 56 million lb/yr
$ value of loss ($2001)	$0.80 million - $0.82 million/yr	$20.0 million - $20.9 million/yr

Source: U.S. EPA analysis, 2002.

C2-3 Ohio River Watershed Study (Large Rivers)

Using facility-generated data, EPA evaluated the impacts of I&E along a 500-mile stretch of the Ohio River, from the western portion of Pennsylvania, along the southern border of Ohio, and into eastern Indiana. EPA evaluated the available I&E monitoring data at nine case study facilities (W.C. Beckjord, Cardinal, Clifty Creek, Kammer, Kyger Creek, Miami Fort, Philip Sporn, Tanners Creek, and WH Sammis) and extrapolated the results to the 20 remaining in-scope facilities in the case study area to derive a cumulative impact estimate for all facilities subject to the proposed rule. The extrapolations were made on the basis of relative operating size (operating MGD) and by river pool (Hannibal, Markland, McAlpine, New Cumberland, Pike Island, and Robert C. Byrd pools).

The results indicate that impingement at the nine case study facilities causes the mortality of approximately 188,000 age 1 equivalents of fishery species per year. This translates into over 9,000 pounds of lost fishery yield annually. In addition, over 6.1 million age 1 equivalents of forage species are impinged each year at the nine case study facilities. For entrainment, the results indicate that about 2.2 million age 1 equivalents of fishery species are lost each year, amounting to some 47,000 pounds of lost fishery yield annually. Entrainment of forage species results in losses of an additional 14.7 million age 1 equivalents each year.

EPA extrapolated loss rates per MGD of intake flow for the nine case study facilities to all other in-scope cooling water intake structures in the Ohio River case study area on the basis of intake flow to estimate the total baseline economic value of I&E at Ohio River facilities. The economic value of these losses is based on benefits transfer-based values applied to losses to the recreational fishery, nonuse values, and the partial value of forage species impacts (measured as replacement costs or production foregone). Average historical losses from all in-scope facilities in the case study area for impingement are valued using benefits transfer at between roughly $0.1 million and $1.4 million per year (in $2001). Average historical losses from entrainment are valued using benefits transfer at between approximately $0.8 million and $2.4 million per year (all in $2001) for in-scope facilities.

EPA also estimated a random utility model to provide primary estimates of the recreational fishery losses associated with I&E in the Ohio River case study area. This primary research results supplement the benefits transfer estimates derived by EPA. The average annual recreation-related fishery losses at all facilities in the case study amount to approximately $8.4 million (in $2001) per year (I&E impacts combined). For the in-scope facilities covered by the proposed Phase 2 rule, the losses due to I&E were estimated via the RUM to amount to approximately $8.3 million per year (in $2001). Results for the RUM analysis were merged with the benefits transfer-based estimates in a manner that avoids double counting, and indicate that baseline losses at in-scope facilities amount to between $3.5 million and $4.7 million per year for impingement and between $9.3 and $9.9 million per year for entrainment (in $2001) (see Table C2-3).

Table C2-3: Baseline Impacts (annual average) in the Ohio River (29 In-Scope Facilities)

Baseline Impacts	Impingement	Entrainment
Age 1 equivalent fish lost	> 11.3 million/yr	> 23.0 million/yr
# lbs lost to landed fishery	> 14,900lb/yr	> 39,000lb/yr
$ value of loss ($2001)	$3.5 million - $4.7 million/yr	$9.3 million - $9.9 million/yr

Source: U.S. EPA analysis, 2002.

In interpreting the results of the case study analysis, it is important to consider several critical caveats and limitations of the analysis. In the economic valuation component of the analysis, valuation of I&E losses is often complicated by the lack of market value for forage species, which may comprise a large proportion of total losses. Forage species have no direct market value, but are nonetheless a critical component of aquatic food webs. EPA included forage species impacts in the economic benefits calculations, but because techniques for valuing such losses are limited, the final estimates may well underestimate the full ecological and economic value of these losses.

In addition, the Ohio River case study is intended to reflect the level of I&E, and hence the benefits associated with reducing I&E impacts, for cooling water impact structures along major rivers of the United States. However, there are several factors that suggest that the Ohio River case study findings may be a low-end scenario in terms of estimating the benefits of the proposed regulation at facilities along major inland rivers of the United States. These factors include the following:

- The I&E data developed by the facilities were limited to one year only, are from 1977 (nearly 25 years ago), and pertain to a period of time when water quality in the case study area was worse than it is currently. This suggests that the numbers of impinged and entrained fish today (the regulatory baseline) would be appreciably higher than observed in the data collection period. In addition, the reliance on a monitoring period of one year or less implies that the naturally high variability in fishery populations is not captured in the analysis, and the results may reflect a year of below average I&E.

- The Ohio River is heavily impacted by numerous significant anthropocentric stressors in addition to I&E. The river's hydrology has been extensively modified by a series of 20 dams and pools, and the river also has been extensively impacted by municipal and industrial wastewater discharges along this heavily populated and industrialized corridor. To the degree to which these multiple stressors were atypically extensive along the Ohio River (in 1977) relative to those along other cooling water intake structure-impacted rivers in the United States (in 2002), the case study will yield smaller than typical I&E impact estimates.

- The Ohio River is very heavily impacted by cumulative effects of I&E over time and across a large number of cooling water intake structures. The case study segment of the river has 29 facilities that are in-scope for the Phase 2 rulemaking, plus an additional 19 facilities that are out of scope. Steam electric power generation accounted for 5,873 MGD of water withdrawal from the river basin, more than 90 percent of the total surface water withdrawals, according to 1995 data from USGS.

Because of these circumstances on the Ohio River, the results EPA obtained for this case study may not underestimate I&E and regulatory benefits on other inland rivers.

In conclusion, several issues and limitations in the I&E data for the Ohio case study (e.g., the reliance on data for one year, nearly 25 years ago), and the many stressors that affect the river (especially in the 1977 time frame), suggest that the results obtained by EPA underestimate the benefits of the rule relative to current Ohio River conditions. The results are also likely to underestimate the benefits value of I&E reductions at other inland river facilities.

C2-4 San Francisco Bay/Delta (Pacific Coast Estuaries)

The results of EPA's evaluation of I&E of striped bass and threatened and endangered and other special status fish species at the Pittsburg and Contra Costa facilities in the San Francisco Bay/Delta demonstrate the significant economic benefits that can be achieved if losses of highly valued species are reduced by the proposed section 316(b) rule. The benefits were estimated by reference to other programs already in place to protect and restore the declining striped bass population and threatened and endangered fish species of the San Francisco Bay/Delta region. The special status species that were evaluated included delta smelt, threatened and endangered runs of chinook salmon and steelhead, sacramento splittail, and longfin smelt.

Based on limited facility data, EPA estimated that the striped bass recreational catch is reduced by about 27,203 fish per year because of impingement at the two facilities and 185,073 fish per year because of entrainment. Estimated impingement losses of striped bass are valued at between $379,000 and $589,000 per year, and estimated entrainment losses are valued at between $2.58 million to $4.01 million per year (all in $2001).

EPA estimated that the total loss of special status fish species at the two facilities is over 431,700 age 1 equivalents per year resulting from impingement and 2.2 million age 1 equivalents per year because of entrainment. Estimated impingement losses of these species are valued at between $12.38 million and $42.65 million per year, and estimated entrainment losses are valued at between $23.1 million and $79.2 million per year (all in $2001).

The estimated value of the recreational losses and the special status species losses combined ranges from $12.8 million to $43.2 million per year for impingement and from $25.6 million to $83.2 million per year for entrainment (all in $2001) (see Table C2-4).

Table C2-4: Baseline Impacts (annual average) for Special Status Fish Species in the San Francisco Bay/Delta (Two In-Scope Facilities)

Baseline Impacts	Impingement	Entrainment
Age 1 equivalent fish lost	> 431,700/yr	> 2..2 million/yr
Number of striped bass lost to recreational catch	27,203	185,073
$ value of combined loss ($2001)	$12.8 million - $43.2 million/yr	$25.6 million - $83.2 million/yr

Source: U.S. EPA analysis, 2002.

In interpreting these results, it is important to consider several critical caveats and limitations of the analysis. No commercial fisheries losses or non-special status forage species losses are included in the analysis. Recreational losses are analyzed only for striped bass. There are also uncertainties about the effectiveness of restoration programs in terms of meeting special status fishery outcome targets.

It is also important to note that under the Endangered Species Act, losses of all life stages of endangered fish are of concern, not simply losses of adults. However, because methods are unavailable for valuing losses of fish eggs and larvae, EPA valued the losses of threatened and endangered species based on the estimated number of age 1 equivalents that are lost. Because the number of age 1 equivalents can be substantially less than the original number of eggs and larvae lost to I&E, and because the life history data required to calculate age 1 equivalent are uncertain for these rare species, this method of quantifying I&E losses may result in an underestimate of the true benefits to society of section 316(b) regulation.

C2-5 Mt Hope Bay Point (New England Estuary)

EPA evaluated cumulative I&E impacts at the Brayton Point Station facility in Mount Hope Bay in Somerset, Massachusetts. EPA estimates that the cumulative impingement impact is 69,300 age 1 equivalents and 5,100 pounds of lost fishery yield per year. The cumulative entrainment impact amounts to 3.8 million age 1 equivalents and 70,400 pounds of lost fishery yield each year.

The results of EPA's evaluation of the dollar value of I&E losses at Brayton Point (as calculated using benefits transfer) indicate that baseline economic losses range from $7,000 to $12,000 per year for impingement and from $166,000 to $303,000 per year for entrainment (all in $2001).

EPA also developed an HRC analysis to examine the costs of restoring I&E losses at Brayton Point. These HRC estimates were merged with the benefits transfer results to develop a more comprehensive range of loss estimates. The HRC results were used as an upper bound and the midpoint of the benefits transfer method was used as a lower bound (HRC annualized at 7 percent over 20 years). Combining both approaches, the value of I&E losses at Brayton Point ranges from approximately $9,000 to $890,00 per year for impingement, and from $0.2 million to $28.3 million per year for entrainment (all in $2001) (see Table C2-5).

Table C2-5: Baseline Impacts (annual average) in Mount Hope Bay (One In-Scope Facility: Brayton Point)

Baseline Impacts	Impingement	Entrainment
Age 1 equivalent fish lost	> 69,300/yr	> 3.8 million/yr
# lbs lost to landed fishery	> 5,100 lb/yr	> 70,400 lb/yr
$ value of loss ($2001)	$9,000 - $890,000/yr	$0.2 mil - $28.3 million/yr

Source: U.S. EPA analysis, 2002.

For a variety of reasons, EPA believes that the estimates developed here underestimate the total economic benefits of reducing I&E at Brayton Point. EPA assumed that the effects of I&E on fish populations are constant over time (i.e., that fish kills do not have cumulatively greater impacts on diminished fish populations). EPA also did not analyze whether the number of fish affected by I&E would increase as populations increase in response to improved water quality or other improvements in environmental conditions. In the economic analyses, EPA also assumed that fishing is the only recreational activity affected.

C2-6 Oceans (New England Coast)

To evaluate potential I&E impacts of cooling water intake structures in oceans of the New England Coast, EPA evaluated I&E rates at the Pilgrim and Seabrook Nuclear Power Plants. EPA estimated that the impingement impact of Seabrook is over 13,000 age 1 equivalent fish and over 1,800 pounds of lost fishery yield per year. The entrainment impact is over 4.5 million age 1 equivalent fish and over 29,300 pounds of lost fishery yield per year. The impingement impact of Pilgrim is over 52,700 age 1 equivalent fish and over 4,200 pounds of lost fishery yield per year. The entrainment impact is over 14.3 million age 1 equivalent fish and over 91,000 pounds of lost fishery yield per year.

EPA's evaluation of I&E rates at Seabrook and Pilgrim indicates that I&E at Seabrook's offshore intake is substantially less than I&E at Pilgrim's nearshore intake. Impingement per MGD averages 68 percent less at Seabrook and entrainment averages 58 percent less. The species most commonly impinged at both facilities are primarily winter flounder, Atlantic herring, Atlantic menhaden, and red hake. These are species of commercial and recreational interest. However, the species most commonly entrained at the facilities are predominately forage species. Because it is difficult to assign an economic value to such losses, and because entrainment losses are much greater than impingement losses, the benefits of an offshore intake or other technologies that may reduce I&E at these facilities are likely to be underestimated. Several important factors in addition to the intake location (nearshore versus offshore) complicate the comparison of I&E at the Seabrook facility to I&E at Pilgrim (e.g., entrainment data are based on different flow regimes, different years of data collection, and protocols for reporting monitoring results).

Average impingement losses at Seabrook are valued at between $3,500 and $5,200 per year, and average entrainment losses are valued at between $142,000 and $315,000 per year (all in $2001) (see Table C2-6). Average impingement losses at Pilgrim are valued at between $3,300 and $5,000 per year, and average entrainment losses are valued at between $523,500 and $759,300 per year (all in $2001). These values reflect estimates derived using benefits transfer.

Table C2-6: Baseline Impacts (annual average) in Oceans of the New England Coast (One In-Scope Facility: Seabrook)

Baseline Impacts	Impingement	Entrainment
Age 1 equivalent fish lost	> 13,000	> 4.5 million/yr
# lbs lost to landed fishery	> 1,800 lb/yr	> 29,300 lb/yr
$ value of loss ($2001)	$3,000 - $5,000	$142,000 - $315,000

Source: U.S. EPA analysis, 2002.

EPA also developed an HRC analysis to examine the costs of restoring I&E losses at Pilgrim. Using the HRC approach, the value of I&E losses at Pilgrim is approximately $507,000 for impingement, and over $9.3 million per year for entrainment (HRC annualized at 7 percent over 20 years) (all in $2001). These HRC estimates were merged with the benefits transfer results to develop a more comprehensive range of loss estimates.

These HRC estimates were merged with the benefits transfer results to develop a more comprehensive range of loss estimates. The HRC results were used as an upper bound and the midpoint of the benefits transfer method was used as a lower bound (HRC annualized at 7 percent over 20 years). Combining both approaches, the value of I&E losses at Pilgrim ranges from approximately $4,000 to $507,00 per year for impingement, and from $0.6 million to $9.3 million per year for entrainment (all in $2001) (see Table C2-7).

Table C2-7: Baseline Impacts (annual average) in Oceans of the New England Coast (One In-Scope Facility: Pilgrim)

Baseline Impacts	Impingement	Entrainment
Losses Using Benefits Transfer		
Age 1 equivalent fish lost	> 52,700 million/yr	> 214.3 million/yr
# lbs lost to landed fishery	> 4,200 lb/yr	> 91,000lb/yr
$ value of loss ($2001)	$3,000 - $5,000/yr	$0.5 million - $0.7 million/yr
Losses Using HRC as Upper Bounds and Benefits Transfer Midpoints as Lower		
Age 1 equivalent fish lost	> 52,700/yr	> 14.3 million/yr
# lbs lost to landed fishery	> 4,200lb/yr	> 91,000 lb/yr
$ value of loss ($2001)	$4,000 - $507,000/yr	$0.6 million - $9.3 million/yr

Source: U.S. EPA analysis, 2002.

C2-7 The Great Lakes

To evaluate potential I&E impacts of cooling water intake structures in the Great Lakes, EPA evaluated I&E rates at J.R.Whiting. EPA estimated that the impingement impact of J.R.Whiting before installation of a deterrent net to reduce impingement is 21.4 million age 1 equivalent fish and over 844,000 pounds of lost fishery yield per year. The entrainment impact is 1.8 million age 1 equivalent fish and 70,000 pounds of lost fishery yield per year. After installation of the deterrent net in 1981, average annual impingement loss at J.R. Whiting was 1.6 million age 1 equivalent fish per year. No entrainment data was available for this time period.

EPA examined the estimated economic value of I&E at J.R. Whiting before installation of the deterrent net to estimate the historical losses of the plant and potential I&E damages at other Great Lakes facilities that do not employ technologies to reduce impingement or entrainment. Average impingement without the net is valued at between $0.4 million and $1.2 million per year, and average entrainment is valued at between $42,000 and $1.7 million per year (all in $2001) (see Table: C2-8).

The midpoints of the pre-net results from the benefits transfer approach were used as the lower ends of the valuations losses. The upper ends of the valuation of losses reflect results of the HRC method for valuing I&E losses. EPA included the HRC-based estimates of the economic value of I&E losses at J.R. Whiting with the transfer-based estimates to provide a better estimate of loss values, particularly for forage species for which valuation techniques are limited.

Table C2-8: Baseline Impacts (annual average) in the Great Lakes (One In-Scope Facility: J.R. Whiting Without Net)

Baseline Impacts	Impingement	Entrainment
Age 1 equivalent fish lost	>21.4million/yr	> 1.8 million/yr
# lbs lost to landed fishery	> 844,300 lb/yr	> 70,000lb/yr
$ value of loss ($2001)	$0.4 million - $1.2 million/yr	$42,000 - $1.7 million/yr

Source: U.S. EPA analysis, 2002.

Impingement losses at J.R. Whiting with an aquatic barrier net are estimated to be reduced by 92 percent , while entrainment losses are not significantly affected. Thus, losses with a net are valued at between $29,000 and $99,000 for impingement and between $42,000 and $1.7 million per year for entrainment (all in $2001) (see Table C2-9).

Table C2-9: Baseline Impacts (annual average) in the Great Lakes (One In-Scope Facility: J.R. Whiting With Net)

Baseline Impacts	Impingement	Entrainment
Age 1 equivalent fish lost	> 1.6million/yr	n/a
# lbs lost to landed fishery	> 62,700 lb/yr	n/a
$ value of loss ($2001)	$29,000 - $99,000/yr	n/a

Source: U.S. EPA analysis, 2002.

C2-8 Large River Tributary to the Great Lakes

EPA estimates that the baseline impingement losses at the Monroe facility are 35.8 million age 1 equivalents and 1.4 million pounds of lost fishery yield per year. Baseline entrainment impacts amount to 11.6 million age 1 equivalents and 608,300 pounds of lost fishery yield each year.

The results of EPA's evaluation of the dollar value of baseline I&E losses at Monroe (as calculated using benefits transfer) indicate that baseline economic losses range from $502,200 to $981,750 per year for impingement and from $314,600 to $2,298,500 per year for entrainment (all in $2001).

EPA also developed an HRC analysis to examine the costs of restoring I&E losses at Monroe. These HRC estimates were merged with the benefits transfer results to develop a more comprehensive range of loss estimates. The HRC results were used as an upper bound and the midpoint of the benefits transfer method was used as a lower bound (HRC annualized at 7 percent over 20 years). Combining both approaches, the value of I&E losses at Monroe range from approximately $0.7 million to $5.6 million per year for impingement, and from $1.3 million to $13.9 million per year for entrainment (all in $2001) (see Table C2-10).

For a variety of reasons, EPA believes that the estimates developed here underestimate the total economic benefits of reducing I&E at the Monroe facility. EPA assumed that the effects of I&E on fish populations are constant over time (i.e., that fish kills do not have cumulatively greater impacts on diminished fish populations). EPA also did not analyze whether the number of fish affected by I&E would increase as populations increase in response to improved water quality or other improvements in environmental conditions. In the economic analyses, EPA also assumed that fishing is the only recreational activity affected.

Table C2-10: Baseline Losses at (annual average) in a Large River Tributary to the Great Lakes (One In-Scope Facility: Monroe using HRC)

Baseline Losses	Impingement	Entrainment
Age 1 equivalent fish lost	> 35.8 million/yr	> 11.6 million/yr
# lbs lost to landed fishery	> 1.4 million lb/yr	> 608,300lb/yr
$ value of loss ($2001)	$0.7 million - $5.6 million	$1.3 million - $13.9 million

Source: U.S. EPA analysis, 2002.

C2-9 National Baseline Losses Due to Impingement and Entrainment at In-Scope Facilities

Using the case study results reported above, EPA calculated the average number of age 1 equivalent fish lost per million gallons of daily average flow at several representative case study sites (one for each waterbody type). EPA then multiplied these average loss values by the estimated total average daily flow at all in-scope facilities in each waterbody category[2]. The result is an estimate of the total number of baseline losses of fish impinged and entrained in cooling water intake structures at in-scope facilities.

[2] To estimate the total average daily flow by waterbody type, EPA applied sample weights based on the sampling design for the 316(b) questionnaires to the reported average daily flows and summed the weighted flows by category to obtain an estimated of total average daily flow at all 550 in-scope facilities, by waterbody type.

The results of this analysis indicate that over 1.1 billion age 1 equivalent fish are lost annually as a results of I&E at the 550 in-scope facilities. Results by waterbody type are presented in Table C2-11. The national economic value of these losses is discussed in *Chapter C3: National Extrapolation of Baseline Losses* of this EBA.

Table C2-11: Estimated Impingement and Entrainment Losses at In-Scope Facilities (values in millions of age 1 equivalents)

Waterbody Type	Facility Used to Extrapolate	Impingement			Entrainment		
		Fishery Species	Forage Species	Total	Fishery Species	Forage Species	Total
Estuary/Tidal River-North Atlantic[a]	Salem (Delaware)	84.69	137.49	222.18	1,418.81	7,080.16	8,498.97
Estuary/Tidal River-South Atlantic/Gulf	Big Bend (Tampa Bay)	4.57	0.80	5.37	134.41	98,593.63	98,728.04
Freshwater Systems	9 Ohio Facilities (Ohio)	3.53	114.93	118.46	40.85	277.73	318.58
Great Lake	JR Whiting (Great Lakes)	528.64	19.58	548.22	43.06	3.67	46.72
Ocean	Pilgrim (Seabrook and Pilgrim)	1.55	0.05	1.60	78.56	356.66	435.22
Total		**622.98**	**272.85**	**895.83**	**1,715.68**	**106,311.85**	**108,027.53**

[a] Based on I&E losses at Salem assuming 100% through-plant mortality. See *Chapter B3: Ecological Risk Assessment* in *Part B:The Delaware Estuary* of the *Watershed Case Study Analysis for the Proposed Section 316(b) Phase II Existing Facilities Rule* for a detailed analysis of I&E losses.

Source: U.S. EPA analysis, 2002.